# Chapter 4
# Restoring a Legacy: Longleaf Pine Research at the Forest Service Escambia Experimental Forest

**Kristina F. Connor, Dale G. Brockway and William D. Boyer**

**Abstract** Longleaf pine ecosystems are a distinct part of the forest landscape in the southeastern USA. These biologically diverse ecosystems, the native habitat of numerous federally listed species, once dominated more than 36.4 million ha but now occupy only 1.4 million ha of forested land in the region. The Escambia Experimental Forest was established in 1947 through a 99-year lease with the T.R. Miller Mill Company of Brewton, AL, to explore all aspects of longleaf pine management. The 1,214-ha tract in southwest Alabama constitutes a unique example of longleaf pine ecosystems in all stages of development. Long-term studies and demonstrations include stand management alternatives, growth and yield of even-aged natural stands, cone production, and fire ecology.

**Keywords** Cone production · Forest management · Longleaf pine · Natural regeneration · Prescribed fire

## 4.1 Background

The Escambia Experimental Forest (Escambia), located in southern Alabama, was created to spur the revival and improved management of forests dominated by longleaf pine (*Pinus palustris* Mill.) Longleaf pine is a high-quality timber species that provided logs, poles, piling, posts, peelers, pulpwood, and naval stores for the building and transportation needs of early European settlers in the southeastern USA (Frost 2006). It was once the backbone of the early southern forest industry and a source of livelihood for southern communities. Referred to as "the most extensive forest ecosystem in North America dominated by a single tree" (Boyer 1997), longleaf pine encompassed 37.6 million ha from southeastern Virginia to eastern Texas. Longleaf pine trees grew in a range of habitats, from the dry sandy hills to the wet

Dr. Boyer is deceased.

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**Fig. 4.1** Young longleaf pine tree after a prescribed fire

flatwoods in the Carolinas, Georgia, Florida, Alabama, Mississippi, and Louisiana. From sea level along the Gulf Coast and the ridges and flats of central Florida, longleaf pine ecosystems reached up to an elevation of 607 m on the rocky hills of northern Alabama and northwestern Georgia (Burns and Honkala 1990).

The diversity and complexity of the understory in longleaf pine forests are indicative of the many habitats they occupy. Wiregrass (*Aristida* spp.) predominates in the sandy soils of the Atlantic and eastern Gulf coastal plains, while warm season grasses such as little bluestem (*Schizachyrium scoparium* (Michx.) Nash) and yellow indiangrass (*Sorghastrum nutans* (L.) Nash) are found on heavier soils in the flatwoods and western Gulf coastal plains (Jose et al. 2006). Fire was the common thread that united these habitats, creating the high understory diversity and making longleaf pine supreme. Frequent burning of these ecosystems ensured their survival. Longleaf pine trees, whether in the seedling (grass stage), sapling, or mature form, are resistant to flames as long as buds are intact and fire intensity is low (Fig. 4.1). Periodic surface fires, whether caused by lightning strikes or intentionally set by Native Americans or settlers, eliminated less fire-tolerant tree and shrub competitors and exposed the bare mineral soil for longleaf pine seed germination and seedling establishment.

Longleaf pine trees have many unique qualities. In addition to their fire tolerance, they are resistant to some of the insects and diseases that beset their southern pine competitors, including rusts (*Cronartium*), fungi (*Heterobasidion*), root rot (*Phytophthora*), pitch canker (*Fusarium subglutinans f. sp. pini* Wollenw. & Reink.), southern pine beetle (*Dendroctonus frontalis Zimmermann*), and tip moth (*Rhyacionia frustrana* (Comstock); see (1) http://edis.ifas.ufl.edu/pdffiles/FR/FR06400.PDF; (2) http://www.gfc.state.ga.us/forest-management/forest-health/pine-bark-beetles/index.cfm; (3) http://www.bugwood.org (all accessed 29 April 2014). They survive on poor-quality, sandy, droughty soils and are adapted to the hurricane zone, where they often rapidly recover from these catastrophic events (Hoyle 2009; Hughes 2006). However, unlike their competitor pines, longleaf pine seedlings resemble a clump of grass more than a tree and can remain in this stage for 1–10 years or more. Upon release, the seedlings grow rapidly, elevating their terminal bud beyond the reach of the next fire's flames and eventually up into the canopy of the forest if growing space is available. But sporadic seed production and this unique grass stage in the regeneration cycle often resulted in establishment failure after logging. That, along with fire suppression, feral hog predation on seeds and seedlings, and interest in short-term rotation forestry resulted in the fragmented, threatened longleaf pine forests we know today.

## 4.2 Decline of Longleaf Pine Ecosystems

The expansion of railroads into the southern forests in the late nineteenth and early twentieth centuries, along with the development of steam-engine logging, accelerated the harvest of longleaf pine trees (Jose et al. 2006). What were once isolated tracts in the vast longleaf pine interior forests were now within easy reach of railway spurs. Steam-powered skidders and other harvesting equipment represented the beginning of mechanized logging, and newly designed band saws increased mill efficiency. These industrial advances accelerated harvesting and reduced the possibility of successful longleaf pine regeneration.

Longleaf pine seed production was sporadic, with an average of 5–7 years between good seed crops (Boyer 1993; Boyer and White 1990). Removal of overstory trees, without regeneration already in place, resulted in decimation of these forests. Thus, at the peak of harvesting operations in the southern forests, there occurred, almost across the whole South, a failure of the longleaf pine to regenerate after logging.

Interruption of the fire cycle was another of the primary causes for longleaf pine regeneration failure. Burning southern forests was a tradition prior to the 1900s, and longleaf pine, a fire-dependent species, thrived. Native Americans and European settlers inhabiting the South set fires in the forests to promote habitat for particular game species, improve forage quality for domesticated animals, ease access by removing dense understory vegetation, fertilize the land (low intensity fires), facilitate travel through forested areas, and promote the growth of berry crops (Croker 1987;

Whitney 1996). However, in the 1930s, a battle raged between those advocating the benefits of controlled fires (i.e., prescribed burning) in longleaf pine forests and those completely opposed to all burning (Croker 1987). Many professional foresters vigorously fought against any use of fire, and a group begun in 1927, the Dixie Crusaders, toured the South spreading a fire prevention message. One newspaper editor, according to Croker (1987) "…condemned as unpatriotic those who would prescribe fire in the forest." In the 1940s, advertising campaigns featuring Smokey Bear, a black bear cub rescued from a wildfire, supported land management agency policies that viewed fire as the enemy, a destructive agent that must be suppressed at all costs. Thus, longleaf pine forests became overgrown with species less tolerant to fire, and longleaf pine either died out completely or became a minor component of the many ecosystems it once dominated.

Another contributing factor to regeneration failure was free-ranging packs of voracious feral hogs, so prevalent throughout the South that their populations at one time supported a meatpacking industry (Frost 2006). In addition to consuming mast crops of acorns and pine seeds, the hogs also showed a marked preference for the starchy roots of longleaf pine seedlings (Lipscomb 1989; Walkinshaw and Otrosina 2002). The few small longleaf pine seedlings that evaded consumption were usually overtopped by hardwoods and competing southern pines.

Other factors contributed to this regeneration failure but the end result was that many landowners abandoned longleaf pine trees as a cash crop. The species was falsely perceived as difficult to regenerate with highly variable establishment survival, slow early growth, and low initial productivity when compared to other southern pines. Millions of acres of forest land once dominated by longleaf pine were planted with loblolly pine (*P. taeda* L.) and slash pine (*P. elliottii* Engelm.), breaking the long southern cultural connection with longleaf pine. While the "piney woods" remained, the predominant tree species had changed. The forests that evoked literary poetry from its inhabitants (e.g. Ray 1999) were disappearing. The longleaf pine forests that now remain are among the most threatened ecosystems in the USA (Noss et al. 1995).

## 4.3 Establishing the Escambia Experimental Forest

The history of the area that now comprises the Escambia parallels that of the longleaf pine forests of the South. Extension of the railroads into southern forests accelerated harvesting, and, from 1900 to 1919, all merchantable longleaf pine trees on the land now occupied by the Escambia were cut (Croker 1987). Throughout the South, harvesting and loss of acreage to agriculture and development reduced longleaf pine forests from 38 million ha to the 1.2 million fragmented ha they occupy today.

The US Department of Agriculture (USDA) Forest Service began establishing research centers throughout the country at about the same time the Escambia forests were being cut. Seven centers built between 1934 and 1947 were located within the native range of longleaf pine, including one at Brewton, AL. On April 1, 1947, the

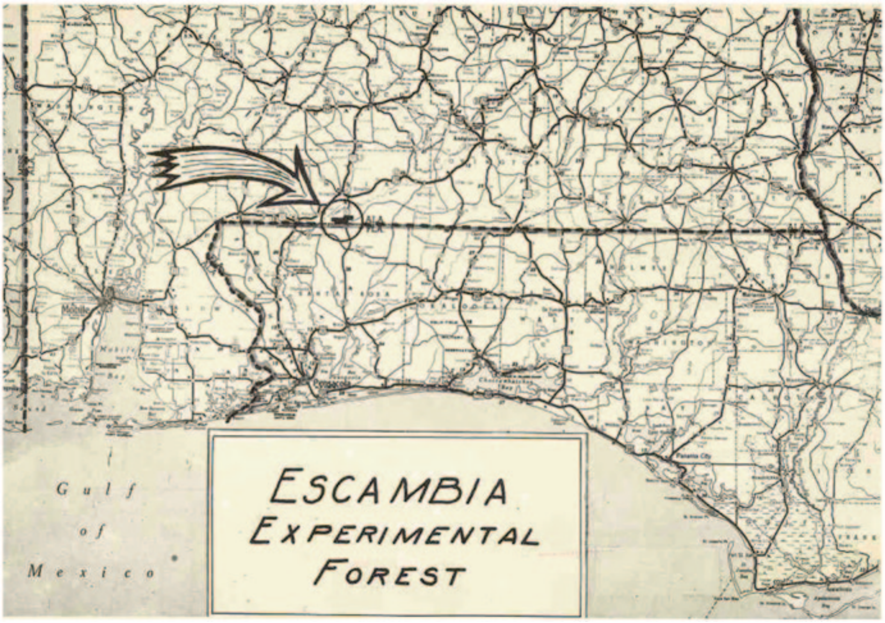


**Fig. 4.2** Reconnaissance survey for a new experimental forest

Escambia was established 7 miles south of the center in Brewton, AL, and was later part of the East Gulf Coast Research Center, Southern Forest Experiment Station (Fig. 4.2). The T.R. Miller Mill Company of Brewton, AL, provided land for the Escambia at no cost to the Forest Service, through a 99-year lease. This 1,214-ha southwest Alabama tract, with trees then averaging 35–45 years of age, was selected because it typified the low-density, second-growth longleaf pine forests that then covered about 25.1 million ha in southern Alabama and northwestern Florida (Croker 1987), and it was centrally located within the species' natural range.

## 4.4 The First Half-Century of Progress

Under the leadership of professional forester Gifford Pinchot, the Bureau of Forestry evolved into the USDA Forest Service in 1905 with increased duties and responsibilities (Pinchot 1947). Unfortunately, while the Forest Service was still in its infancy, the longleaf pine forests were already falling under the axe. The southern timber industry and the communities dependent upon logging were booming. By the time professional foresters began gathering data on growth and yield, regeneration methods, and management techniques for American tree species, the vast longleaf pine forests were well on their way to becoming a historical footnote. Therefore, research at the Escambia was initially focused on solving basic management problems that plagued longleaf pine, such as natural regeneration, thinning regimes,


**Fig. 4.3** Farm Forty Field Days: preparing the harvest for display (**a**); informing and advising the public (**b**, **c**)

and product rotation lengths (Croker 1952, 1958). The intent was to focus efforts on developing practical management alternatives in order to encourage retention of longleaf pine by the owners of the small farm forests that dominated the South. To that end, the Escambia was surveyed and divided into 16.2-ha compartments, and three studies were immediately installed:

a. *The Management Systems Study* The Management Systems Study was established in 24 of Escambia's 16.2-ha compartments, with 12 compartments randomly assigned to even-aged and 12 to uneven-aged management systems. The goal was to examine forest management and economic aspects of three rotation lengths for longleaf pine forests: short (40 years), medium (60 years), and long (80 years;) (Croker 1973). The study measured growth and yield, and management costs, and required a labor-intensive 100% inventory each year. Every tree harvested, whether log, pole, or pulpwood, was scaled in the woods and then again at the T.R. Miller company scale. Volume estimates made in the field were compared with company tickets. Croker (1987) reported truck miles, mule upkeep, labor rates, and equipment costs among the information recorded annually.
b. *The Farm Forty Study* The Farm Forty Study demonstrated management of a typical 16.2-ha longleaf pine farm woodlot. It was managed for logs and poles on an 80-year rotation. An annual field day was held to showcase the products harvested from the woodlot in an average year (Fig. 4.3a–c) (for a 30-year summary,

**Fig. 4.4** An aerial view of an early seed-tree harvest on the Escambia Experimental Forest

see Boyer and Farrar 1981). Harvest was limited to two thirds of the computed annual growth on the woodlot (Croker 1987) and used the group shelterwood stand reproduction method, in which 5-acre groups of trees were periodically removed to encourage natural longleaf pine regeneration (Baker 1934).

c. *The Investment Forest Study* The Investment Forest Study was set up to simulate forest management of a typical investor. Records were kept of all activities on the 259-ha tract, such as timber marking, maintenance of roads and boundary lines, and prescribed burning (Croker 1973). It was managed on a 60-year rotation.

Two other significant events occurred in 1947, the consequences of which still resonate today. One was a bumper seed crop of longleaf pine, and the second was a decision to intentionally burn 10,522 ha of land on both the Escambia and the Conecuh National Forest (Croker 1987). H.O. Mills, a district ranger on the nearby Conecuh, noted a good crop of cones and with the support of Don Morris, an assistant forest supervisor, discussed performing a seedbed burn. They sought the help of Escambia employees Dave Bruce and Thomas Croker, who supported the decision to burn (Croker 1987). The resulting successful establishment of longleaf pine seedlings on burned areas was evidence of what could be achieved by noting patterns in nature and applying sound research to silvicultural problems. Fire, long considered a forest enemy, was now viewed as necessary for successful longleaf pine stand establishment. Croker (1987) wrote that almost all of the prolific advanced regeneration in his seed-tree study (Fig. 4.4) occurred before the study began and prior to the cutback to seed-tree densities. It was the 1947 seed crop that regenerated the site and not the harvest using the seed-tree method. Many of the third-growth forests at the Escambia were established from this one seed crop, and the seed-tree stand reproduction method for longleaf pine was abandoned at the Escambia. Not only did the seed-tree method result in poor regeneration, but it also provided insufficient quantities of pine needles and other fine fuels to carry prescribed fire across the study sites (Drs. Dale Brockway and William Boyer, U.S. Forest Service, pers. comm.).

In 1951, organizational changes in the research stations resulted in formation of the East Gulf Coast Branch, with Brewton as a subunit. Personnel changes and reduced research funds (US $15,000 for salaries and operating expenses; Croker 1987) resulted in simplification of the laborious Management Systems Study at the forest (Croker 1953). Other studies were put on a maintenance basis to conserve funds, and efforts were concentrated on the Farm Forty Study and Investment Forest Study. However, in 1955, with strong local support from the community and from a forest industry desirous of supporting science-based forestry, young foresters were hired to assist with research studies and management data. One of these, William D. (Bill) Boyer, later became project leader of the research unit responsible for managing the Escambia.

In 1956, Croker suggested that the shelterwood stand reproduction method should be used to regenerate longleaf pine forests (Croker 1956; Boyer 1963; Croker and Boyer 1975). His writing showcased this regeneration method as addressing longleaf pine's sporadic seed production and the need for advanced regeneration before release cuts. While the seed-tree method (with residual basal areas between 2 and 3.5 $m^2$/ha) resulted in understocked stands with low volume accretion and hardwood encroachment or severe competition from native grasses, the shelterwood method (with residual basal areas from 5.7 to 7 $m^2$/ha) retained considerable growing stock and waited until adequate reproduction was established before overstory removal. Croker's suggested use of this even-aged technique has benefited many longleaf pine growers throughout the South. Following the successful Farm Forty Study and Tom Croker's publication in the *Journal of Forestry* emphasizing the benefits of the shelterwood reproduction method, land managers began rethinking their approach to longleaf pine regeneration and stand management methods.

Recognizing that the clearcutting and seed-tree methods resulted in insufficient longleaf pine regeneration, Forest Service scientist Dr. Robert M. (Bob) Farrar initiated a study at the Escambia to examine the unexplored effects of uneven-aged management on longleaf pine stands (Farrar 1996). The objective of the study was to demonstrate and compare three uneven-aged management techniques with fixed basal area per acre (target BA = 12.7 $m^2$/ha). Plot sizes range from 12.1 to 16.2 ha. Fire is applied every 3 years, and the diameters of all trees on the study sites are measured every 5 years. All are techniques to maximize timber volume growth and may not always be well suited for achieving ecosystem management goals requiring variable stand structures. Phase 1 was established in 1977 using the volume-guiding diameter limit (V-GDL) technique for volume regulation. Phase 2 of the study was installed in 1981 employing the basal area-maximum diameter-diminution quotient (BDq) technique for structural regulation. Phase 3 was added in 1991, testing the diameter limit cutting (DLC) technique, in which a prescribed basal area is maintained by removing all trees over a specific diameter. Although easy to apply, it is not necessarily the best approach to use for improving a stand, and misapplication can easily degenerate into "high grading" that will seriously undermine the genetic diversity of a forest by removing only the best-quality trees. The diameter class

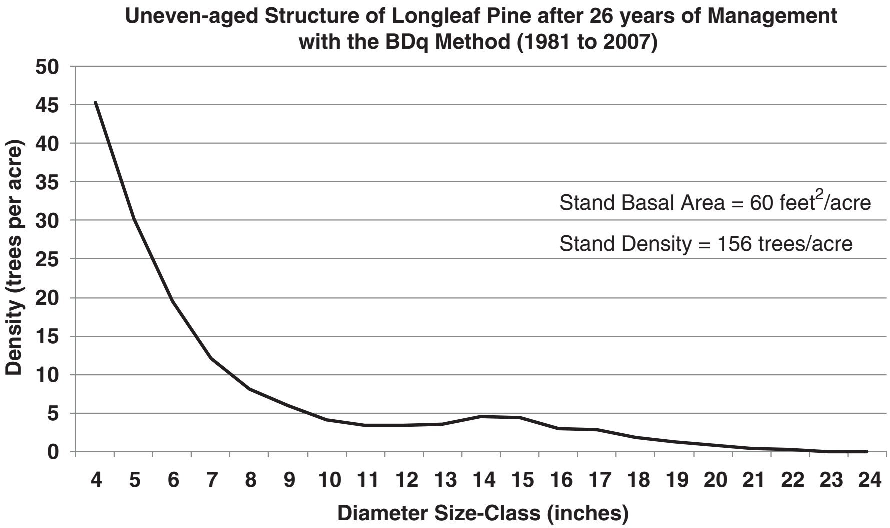


**Fig. 4.5** Diameter distribution in an uneven-aged longleaf pine management demonstration, after 26 years of treatment with the basal area-maximum diameter-diminution quotient (BDq) method at the Escambia Experimental Forest. All data were collected in customary English units

distribution of pines from the BDq study, 26 years after installation, can be seen in Fig. 4.5. From such information, researchers discerned that this technique resulted in adequate regeneration to reproduce the stand and that growth could be sustained through periodic thinning on a 10-year cutting cycle.

In 1964, Farrar, working with partners in the Forest Service Regional Office in Atlanta and collaborators at Auburn University, established a much needed growth and yield study for naturally regenerated longleaf pine that was later expanded region-wide to several locations in Alabama, Mississippi, Florida, Georgia, and North Carolina (Kush and Tomczak 2007). Nearly half of the 305 plots in this study are located at the Escambia. While some plots on other study sites have been lost to development or otherwise destroyed, those at the Escambia remain protected and intact. The objective of the study, which continues today, is to quantify the growth and yield of natural, thinned longleaf pine forests spanning a range of ages, site types, and residual stand densities across the Southern Region. When the study began, site quality was measured by site index at base age 50 to be 15.2–27.4 m, and stand ages were determined to be 20–80 years. Study sites now are thinned to maintain the target basal area for each stand of 2.8–13.9 m$^2$/ha, and new stands in the 15-year age class are added every 10 years for temporal replication. All plots are remeasured every 5 years, with the 50-year remeasurement scheduled to take place in 2014.

Cone production studies at the Escambia date back to 1958 and, since 1966, these have been expanded to observe longleaf pine cone production throughout the region, as part of a shelterwood study entitled "Longleaf Regeneration Trials." Scientists still annually monitor mature longleaf pine trees from Louisiana to North

**Table 4.1** Average total basal area (feet²/acre) and volume (feet³/acre) for different season and frequency of prescribed fire treatments on the Escambia Experimental Forest. Numbers in italic are significantly different than the other numbers in the column at a probability ≤0.05. All data were collected in customary English units (From Kush 2007)

| | Basal Area | | | | | | Volume | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1984 | 1987 | 1990 | 1994 | 1999 | 2004 | 1984 | 1987 | 1990 | 1994 | 1999 | 2004 |
| *Treatment*[a] | | | | | | | | | | | | |
| Winter-2 | 11 | 25 | 39 | 62 | 86 | 111 | 74 | 256 | 546 | 1,155 | 1,869 | 2,840 |
| Spring-2 | 11 | 23 | 38 | 61 | 80 | 104 | 76 | 236 | 524 | 1,125 | 1,750 | 2,639 |
| Winter-3 | 11 | 26 | 41 | 63 | 87 | 112 | 78 | 275 | 595 | 1,208 | 1,969 | 2,966 |
| Spring-3 | 12 | 27 | 44 | 68 | *94* | 114 | 80 | 268 | 612 | 1,300 | 2,096 | 2,987 |
| Winter-5 | 21 | 25 | 40 | 65 | 89 | 116 | 86 | 262 | 573 | 1,230 | 1,969 | 3,022 |
| Spring-5 | 13 | 26 | 42 | *71* | *97* | *127* | 94 | 284 | 608 | 1,366 | *2,199* | *3,340* |
| No burn | 11 | 27 | 45 | *74* | *102* | *127* | 72 | 274 | 638 | 1,468 | *2,390* | *3,460* |

[a] Treatments are prescribed burning during the winter or spring season at a 2-, 3-, or 5-year interval

Carolina, tallying the number of longleaf pine flowers, conelets, and cones to assess and predict longleaf pine seed production for the current and following years (Boyer 1974, 1987, 1998; Croker 1973). After many years of observing cone production in stands across a range of densities, optimum cone production appears to occur in shelterwood stands of 6.2 m²/ha. Scientists monitor 10–15 seed-bearing longleaf pine trees per study site and annually conduct pollen counts at the Escambia. Continuing Bill Boyer's earlier work, Dr. Dale Brockway annually prepares a report containing estimates for the regional cone crop. It is issued in June and is in high demand by southern forest managers.

As evidence supporting the role of fire in longleaf pine forests grew and appreciation for the importance of fire in successful seedling establishment increased, scientists formally began research on fire ecology in 1973 by establishing two continuing studies at the Escambia (Kush et al. 1999). To investigate the long-term effects of season of burn, plots are either burned once every 2 years in spring, summer, or winter, or left unburned as a control. In conjunction with the season of burn, some plots received an initial herbicide treatment while on others vegetation was periodically cleared away by hand. All pine height and diameters were measured, fire behavior documented every 3 years, and crown scorch recorded shortly after each burn. Understory species were also identified and measured. Still in progress, the study measurements are now repeated every 5 years.

A second fire study was established in 1985 to examine both fire season and the length of time between burns (i.e., one fire every 2, 3, or 5 years; Boyer 1990, 1994). Prescribed burning during the spring, rather than in summer or winter, enhanced longleaf pine seedling development and was also very effective in controlling hardwoods (Boyer 1990). Burning at 2-year intervals resulted in lower overstory basal area and volume growth than burning at either 3-year or 5-year intervals (Kush 2007; Whitaker et al. 2007; Table 4.1). The increased interval between burns places less stress on the trees and therefore increased growth.

## 4.5 Current and Future Directions

Through the decades of decline, longleaf pine forests retained supporters and admirers. In addition to those with memories of tapping pine trees for turpentine and collecting longleaf pine needles to weave baskets, remembering marvels of pitcher plant bogs and encounters with gopher tortoises, there were always those who recognized the timber production potential of this species and worked to promote and sustain research and practical management activities.

In 1974–1975, the headquarters for the research work unit managing the Escambia was relocated from Brewton, AL, to Auburn, AL. The future direction of forestry appeared to be moving away from the long rotations that produced high-value longleaf pine poles and sawlogs toward short rotations featuring loblolly pine and slash pine. Among the new objectives for the research unit was increased emphasis on herbicide control of undesirable weeds and hardwood vegetation (Dr. Bill Boyer, U.S. Forest Service, pers. comm.). The Escambia was scheduled for termination and only the combined efforts of Bill Boyer and Robert Farrar kept the land under Forest Service management. They argued that fire was an alternative means for natural hardwood control and that the fire studies on the Escambia would provide much needed information. Many of our existing databases and long-term records were maintained "unofficially" by Boyer who continued collecting data despite elimination of funds for longleaf pine research and the shift in research emphasis. Pleas for maintaining a research presence at the Escambia were still being made as late as 1987, stressing that the forest would be "…impossible to replace, quantitatively and qualitatively" (Boyer and Farrar 1987).

The persistent belief of Boyer and Farrar in the value of longleaf pine research to southern communities and to the southern timber industry was strengthened in 1995 with formation of the Longleaf Alliance (http://www.longleafalliance.org). This group was established to coordinate partnerships among the various parties—private landowners, educational institutions, state and federal governments, nongovernmental organizations, and industry groups—interested in longleaf pine. While interests in longleaf pine range from industrial forest management to complete ecosystem restoration, almost all of the 800 members of the Longleaf Alliance want to not only manage and restore longleaf pine forests but also promote increased interest in this species. Because of these individual and group efforts, research at the Escambia Experimental Forest has been continuous since its establishment in 1947. The long-term data sets collected by scientists from this forest are considered both invaluable and unique.

A little more than 80 % of the Escambia is now occupied by longleaf pine stands, with the remainder in slash pine and hardwood bottomlands. Tree ages range from young seedlings to 160-year-old trees with the second-growth timber approximately 95 years old. More than 485.6 ha of the forest have been naturally regenerated, and more than half of this is in stands ranging from 35 to 50 years in age. Stand densities vary widely, with some variation artificially created for the growth and yield studies started in 1964. Site index as a measure of site quality averages 21.3–22.9 m at age 50 years, with a range from 19.8 to 25.3 m. Very few locations in the South

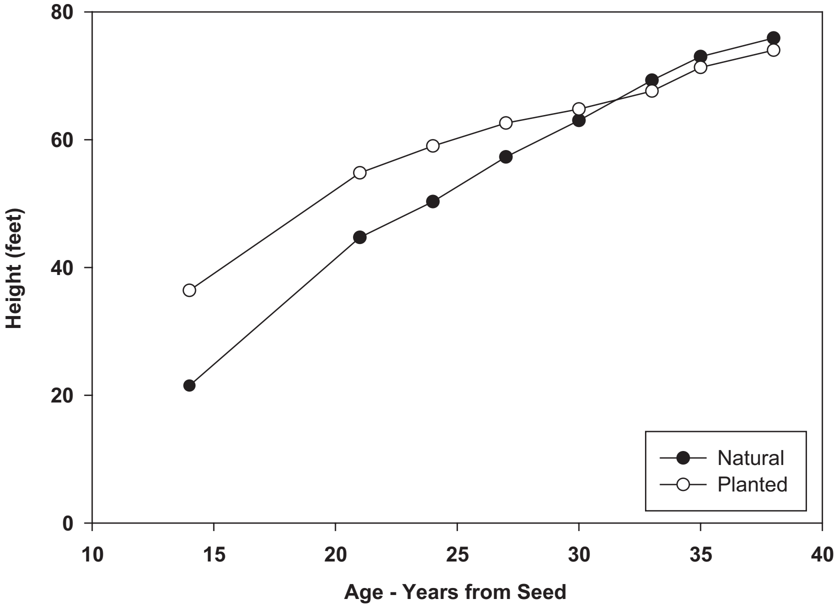


**Fig. 4.6** Changes in longleaf pine total height: natural stands versus plantations on prepared sites. All data were collected in customary English units

can boast the combinations of stand ages, forest structures, and site conditions that are found at the Escambia.

The advantages of the long-term work in progress at the Escambia are exemplified by discoveries that could not have been made through short-term experiments. For instance, Boyer (1997) observed that natural longleaf pine regeneration catches and surpasses planted longleaf pine in height, even with understory control on the planted sites (Fig. 4.6). While planted longleaf pine trees on intensively prepared sites had a 4-m-height advantage at age 13 over natural regeneration on unburned sites, the difference had closed to 1.5 m by age 26. The height of naturally regenerated trees caught up to and surpassed planted trees by age 33. For a landowner or forest manager with longleaf pine already in place, natural regeneration methods are both effective and economical, eliminating the large sums needed for tree planting and intensive site preparation costs that, carried over years, diminish the economic benefit to the forest owner.

A study at the Harrison Experimental Forest near Gulfport, MS, has implications for the Escambia and for landowners throughout the South. In addition to exhibiting greater resistance to the many insect and disease pests that infect other southern pines, longleaf pine outgrows loblolly pine and is comparable in growth to slash pine by age 39 years (Harris et al. 2001; Table 4.2). Additionally, nearly 71 % of the longleaf pine trees in the study produced poles, while only 12 % of slash pine and 8 % of loblolly pine trees fell into that classification. Poles are consistently valued at about 150 % of sawtimber stumpage prices, making longleaf pine a far superior

**Table 4.2** A comparison of basal area, diameter at breast height, total height, and volume of longleaf pine, slash pine, and loblolly pine at ages 25 and 39 years. Means followed by different letters indicate a significant difference between species within the same column. All data were collected in customary English units (Reproduced from Harris et al. 2001)

| | Density (trees/acre) | | Basal area (feet$^2$/acre) | | DBH (inches) | | Height (feet) | | Volume (feet$^3$/acre) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1985 | 1999 | 1985 | 1999 | 1985 | 1999 | 1985 | 1999 | 1985 | 1999 |
| Longleaf | 154a | 140a | 49.51a | 68.51a | 7.44b | 9.42ab | 55.1a | 68.7b | 2,802ab | 4,918a |
| Slash | 151a | 120b | 43.06b | 59.90a | 7.83a | 9.66a | 56.7a | 79.1a | 2,908a | 4,475a |
| Loblolly | 132b | 99c | 47.95ab | 50.02b | 7.47b | 9.17b | 63.4b | 63.4c | 2,467b | 3,580b |

**Table 4.3** Comparison of site index at base age 50 years (SI) for second-growth and third-growth longleaf pine forests at the Escambia Experimental Forest. All data were collected in customary English units (From Boyer 2001)

| Compartment | 2nd Growth | | | | 3rd Growth | | | |
|---|---|---|---|---|---|---|---|---|
| | No. of plots | Age | Height | SI | No. of plots | Age | Height | SI |
| 74 | 8 | 60.8 | 72.5 | 67.9 | 7 | 41.5 | 72.7 | 81.2 |
| 75 | 8 | 63.4 | 72.4 | 65.8 | 7 | 38.8 | 75.0 | 84.8 |
| 81 | 5 | 59.4 | 74.1 | 68.7 | 10 | 39.6 | 74.3 | 84.2 |
| 83 | 9 | 55.3 | 69.9 | 66.9 | 6 | 39.2 | 76.8 | 87.2 |
| 102 | 7 | 50.6 | 65.5 | 65.9 | 14 | 40.3 | 71.1 | 80.6 |
| 103 | 8 | 55.8 | 64.4 | 61.6 | 14 | 40.8 | 68.9 | 77.1 |
| 107 | 9 | 46.0 | 67.3 | 70.1 | 6 | 40.0 | 74.7 | 84.6 |
| 115 | 11 | 55.0 | 64.2 | 61.8 | 7 | 40.7 | 73.1 | 82.6 |
| 125 | 9 | 51.1 | 58.8 | 60.6 | 7 | 39.7 | 75.2 | 85.8 |
| *Mean* | | *55.3* | *67.7* | *65.5* | | *40.1* | *73.5* | *83.1* |

investment for the forest landowner (for examples from two southern states, see Alabama Cooperative Extension System Reports and Mississippi State University Extension Notes at http://www.aces.edu/pubs/docs/A/ANR-0602/ and http://msucares.com/forestry/economics/reports/2009_harvest_report.pdf, respectively: accessed 8 April 2010). Longleaf pine is therefore a better economic choice than either loblolly or slash pine. Furthermore, a post-Hurricane Katrina survey and analysis showed that longleaf pine suffered substantially less damage and mortality than either slash pine or loblolly pine (Johnsen et al. 2009).

Boyer (2001) noted significant growth differences between second-growth and third-growth stands at the Escambia (Table 4.3). Examining data collected from two early studies, he noticed that estimates of site index for third-growth stands exceeded that obtained when second-growth stands were first inventoried. In 16 compartments, second-growth stands averaged 20.3 m in one study and 20.2 m in a second, while estimates of height growth in third-growth stands from studies in 17 compartments averaged 24.8 m. All of these stands are intermixed and cover a similar range of soil-site conditions. Additionally, less than 5 % of second-growth trees in the study showed signs of early suppression followed by later release. In fact, based on early radial growth measurements of the first 25 rings, second-growth

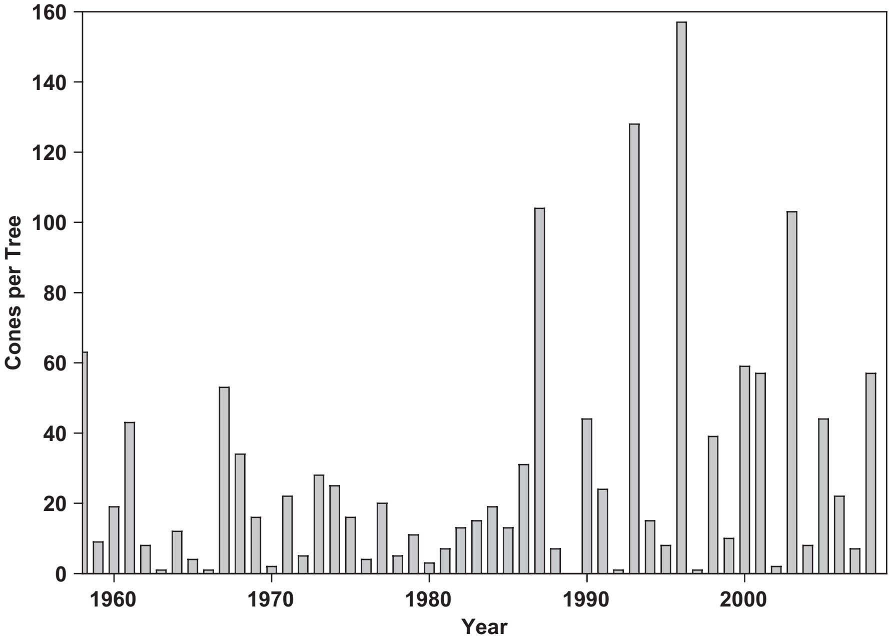


**Fig. 4.7** Longleaf pine cone production on the Escambia Experimental Forest from 1958 to 2008

trees outgrew third-growth trees, suggesting that changes in growth are not due to differences in site, stand density, or early tree growth. Using 9 of the 16 compartments that included third-growth stands approximately 40 years of age, he made direct comparisons of the site index values and confirmed this significant site index shift. While further measurements are necessary, this study may have significant implications for climate change researchers.

Scientists are now examining data from the long-term growth and yield studies to determine whether the carbon storage capacity of longleaf pine could provide potential mitigation for climate change. Kush et al. (2004) noted that changes in the wood/fiber markets in the South resulted in a trend toward longer tree rotations. Since longleaf pine is a long-lived species with a low mortality rate and produces highly valued sawlogs and poles, it is an ideal candidate for long-term terrestrial carbon storage. Even after harvest, the wood products will continue to store carbon in the form of poles, building timbers, and veneers. There would also be both social and ecological benefits from increased restoration of longleaf pine acreage. Kush et al. (2004) also noted that longleaf pine outperforms other southern pines as the rotation lengthens and is tolerant of fire and many insects and diseases that decimate loblolly pine and slash pine.

Lastly, cone crop information that has been collected for 50 years on the Escambia and at many sites across the region in the “Longleaf Regeneration Trials” has produced interesting results. Because of this extensive long-term database, scientists have noted that cone production by longleaf pine trees on the Escambia has more than doubled during the period from 1986 to 2008 compared to the preceding 20-year average (Fig. 4.7). At this time, researchers are uncertain about the cause for this increasing frequency of good cone crops. While it may be a result of the same factors affecting site index of the third-growth stands, observers speculate that the increase may be related to advancing tree age, geographic origin of the species, or climate change. More research is needed to study these phenomena.

These important advances were possible only because of the long-term databases now available from experimental forests such as the Escambia, where studies have been actively maintained and protected for decades of information gathering. Because of research at the Escambia, we now know that the shelterwood reproduction method is a successful and cost-efficient means of regenerating longleaf pine forests, that fire is essential for longleaf pine regeneration and ecosystem maintenance, that height growth of naturally regenerated longleaf pine catches up to and surpasses planted seedlings after 33 years, and above all, that longleaf pine ecosystems are an integral and vital part of the southern culture.

The Escambia Experimental Forest is managed by the USDA Forest Service, Southern Research Station, Unit SRS-4158, headquartered in Auburn, AL, with scientists also stationed at Clemson, SC, and Pineville, LA.

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